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THE DIGITAL AIR DEFENSE MISSILE SYSTEM SIMULATION TECHNICAL EFF--ETC(U)
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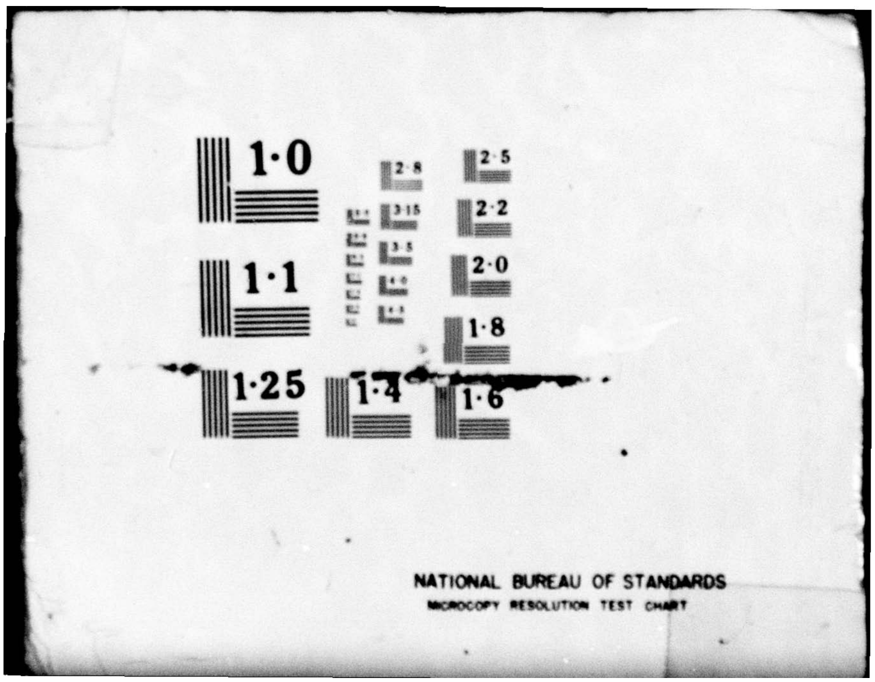
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THE DIGITAL AIR DEFENSE MISSILE SYSTEM
SIMULATION TECHNICAL EFFORT.

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PREFACE

This report summarizes the work performed by M&S Computing, Inc., for the Guidance and Control Directorate, U.S. Army Missile Technology Laboratory, U.S. Army Missile Command, Redstone Arsenal, Alabama, under Contract No. DAAK40-D-79-0003, Work Order No. 002. James A. McLean was the contract monitor for this effort, which was performed during the period of May 14, 1979, to September 30, 1979.

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1. INTRODUCTION

M&S Computing, Inc., has provided engineering and programming support to develop, modify, and utilize existing Guidance and Control simulation software, and has performed studies to determine system performance in assorted operational modes.

1.1 Purpose

This document summarizes the accomplishment of M&S Computing, Inc., for the past five months under Contract No. DAAK40-D-79-0003, Work Order 002.

1.2 Organization

The remainder of this document is divided into sections described below.

Section 2 describes the digital area correlator model developed by M&S Computing, Inc.

Section 3 describes the system analysis support provided by M&S Computing.

2. DIGITAL AREA CORRELATOR MODEL

During this contract, M&S Computing provided design, development and programming support for a digital area correlator computer model. These tasks will be discussed in the following paragraphs.

2.1 Geometrical Layout of the Digitized Live Radar and Reference Images

The digital area correlator model requires as input two sets of digitized images, the first being a reference image set, generated prior to flight, of the selected target area. The reference image set consists of four images constructed for the four separate altitude bands of the terminal guidance phase of a missile flight. Figure 2-1 shows a general layout of the reference image. The reference image area is a circular area of N pixels in diameter, where each pixel magnitude represents a digitized radar return magnitude. Initially each pixel of both the live radar and reference images is digitized with an amplitude in the range of 0 to 255. These pixel values are then converted to one of three levels based on an upper and lower threshold selection.

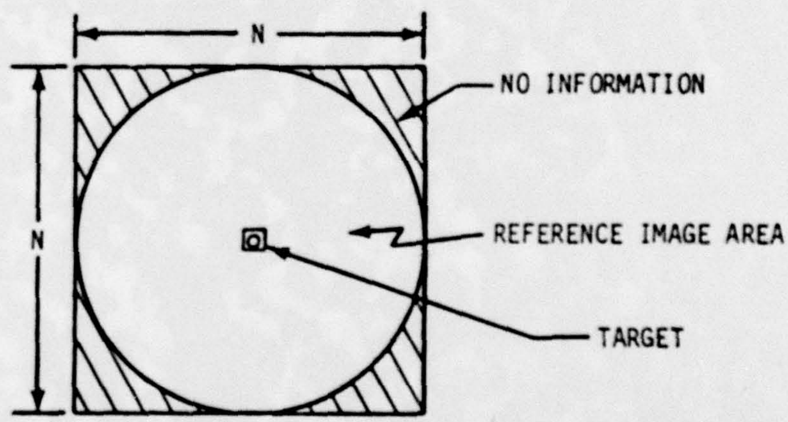

Figure 2-1. Geometrical layout of a reference image.

The live radar image layout is somewhat different from the reference image. Figure 2-2 shows the geometrical layout of the live radar image. Due to the imaging radar characteristics, no returns are received in the circular center portion of the radar scan as shown in Figure 2-2. The live radar image is a circular area of M pixels in diameter, where $M < N$.

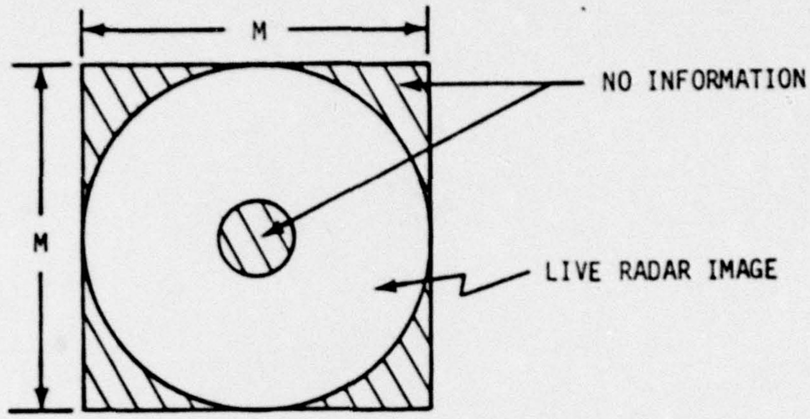

Figure 2-2. Geometrical layout of a live radar image.

2.2 Mean Absolute Difference Algorithm

The digital area correlator implements a tri-level mean absolute difference correlation algorithm. This algorithm in its normalized form is illustrated in Equation (1).

$$\phi_{LR}(E,N) = 1 - \frac{\sum_{X=1}^{M} \sum_{Y=1}^{M} \left\{ \left| L_q(X,Y) - R_q(E+X,N-Y) \right| M(X,Y) \right\}}{2 \sum_{X=1}^{M} \sum_{Y=1}^{M} M(X,Y)} \tag{1}$$

where:

E and N represent discrete pixel search locations with ranges

$E_0 \leq E \leq E_0+31$ and $N_0-31 \leq N \leq N_0$

to yield a 32 x 32 pixel search region;

E_0 and N_0 are pixel search start locations in the reference image;

$\phi_{LR}(E,N)$ is the computed correlation function between the live radar image and the reference image as a function of the east and north search locations;

$L_q(X,Y)$ is the live radar image quantized to three levels;

$R_q(E+X, N-Y)$ is the reference image quantized to three levels;

$M(X,Y)$ is a live radar mask image quantized to two levels to denote which of the M x M pixels of the live radar image to include in the correlation calculation.

The algorithm described by Equation (1) can be modeled as three separate processes. These processes are:

1. Three-level quantization of the live radar and reference images.

2. Calculation of the absolute difference at each pixel location represented by the double summation in the numerator of Equation (1).

3. Determination of the live radar mask array.

These processes will be addressed individually in the next sections.

2.3 Three-Level Quantization Model

The transfer function of a three-level quantizer is shown in Figure 2-3. In Figure 2-3 the input signal is assumed to be zero mean. The parameters TU and TL in Figure 2-3 represent upper and lower slice thresholds, respectively. Assuming $L(X,Y)$ to be the radar intensity return for pixel (X,Y) and $L_q(X,Y)$ to be quantized value of $L(X,Y)$, then the quantization process is given by Equation (2).

$$L_q(X,Y) = \begin{cases} 1 , & L(X,Y) \geq TU \\ 0 , & TL < L(X,Y) < TU \\ -1 & L(X,Y) \leq TL \end{cases} \qquad (2)$$

By reducing the image intensity from 256 levels to three levels each pixel can be represented by two bits of information as opposed to eight bits.

Selection of the upper and lower slice thresholds for the live radar and reference images is a critical item and will require further study through simulation and analysis.

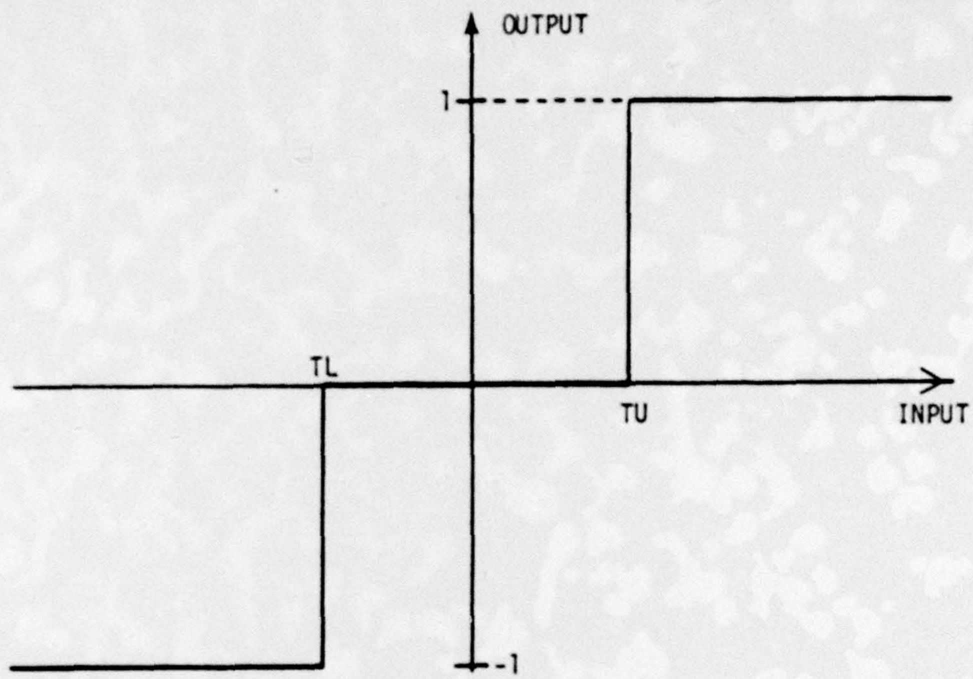

Figure 2-3. Three-level quantizer.

2.4 Exclusive-Or Representation

Since the live radar and reference images are sliced to three levels, the absolute difference function, given in Equation (1), can be implemented using a bitwise exclusive-or function. The equivalence of these two functions can be shown by proper selection of the two bit pixel codes used in the three level images. Assuming L_q (X,Y) and R_q (E+X,N-Y) represent the quantized live radar and reference images, Figure 2-4 shows the possible outcomes of the absolute difference function by applying the quantization levels of Figure 2-3.

R_q \ L_q	-1	0	1
-1	0	1	2
0	1	0	1
1	2	1	0

Figure 2-4. Possible outcomes of $|L_q(X,Y) - R_q(E+X,N-Y)|$

Now if the three quantization levels shown in Figure 2-3 are translated to a two-bit code as

$$1 \longrightarrow 01$$

$$0 \longrightarrow 00$$

$$-1 \longrightarrow 10$$

the outcome of the bitwise exclusive-or function is given in Figure 2-5. By inspecting Figure 2-5, it can be seen that by counting the number of bits set in the result, the two functions yield the same value to the correlation calculation, and thus are equivalent.

R_q \ L_q	10	00	01
10	00	10	11
00	10	00	01
01	11	01	00

Figure 2-5. Possible outcomes of $L_q \oplus R_q$.

2.5 Determination of the Live Radar Mask Array

As shown in Figure 2-2 the live radar return is only active in a circular doughnut-shaped area of the live radar array. It is the function of a mask array to determine which pixels in the live radar image are active and used in the correlation calculation of Equation (1). The mask array is a function of altitude and must be updated when a new live radar image is acquired. Figure 2-6 shows the radar geometry used to determine the mask array. Assuming R_1 and R_2 to be the radial limits of the active radar area and R_{xy} to be the radius to pixel (X,Y) in the live radar image, the mask value, M(X,Y), is one if $R_1 \leq R_{xy} \leq R_2$ and zero otherwise. R_1 and R_2 are determined as

$$\begin{aligned} R_1 &= H \tan(\theta_1) \\ R_2 &= H \tan(\theta_2) \end{aligned} \qquad (3)$$

where θ_1 and θ_2 are known radar scan angles and H is the indicated altitude.

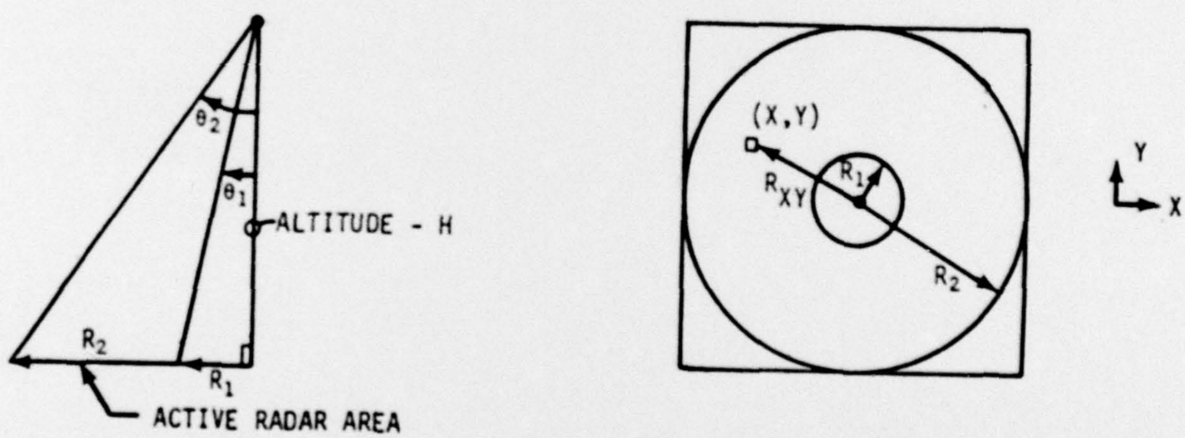

Figure 2-6. Radar geometry.

2.6 Block Diagram of the Area Correlator Simulation

A simulation of a digital area correlator using radar images has been written using FORTRAN programming language. Figure 2-7 gives a block diagram of this simulation. The subroutines written to implement the simulation will be summarized in this section.

1. Program DGCOR1 - This is the main program for the digital area correlator simulation.

2. Subroutine LOAD1 - This routine performs the three level slicing of the live radar images, codes the pixels to 2 bits and packs the images to 8 pixels per computer word.

3. Subroutine LOAD2 - This routine performs the same functions as LOAD1 using the reference images as input.

4. Subroutine MASK1 - This routine sets up a mask array of pixels which only allows valid pixels to take part in the correlation point calculation. The number of valid correlation points is returned by this routine and is used for correlation surface normalization.

5. Subroutine MAD1 - This routine schedules other routines necessary to calculate a 32 x 32 normalized correlation surface using the mean-absolute difference algorithms.

6. Subroutine WRDEOR - This routine performs the bitwise *exclusive-or between the live radar and reference* radar images for each row in live radar image and counts the number of mismatching bits on each call.

7. Subroutine SHIFT - This routine performs the necessary bit shift operations on the reference images to calculate the next correlation point on the surface.

8. Subroutine MAXIM - This routine locates the maximum value of the normalized correlation surface and identifies the coordinates of this match point.

9. Subroutine PRINT2 - This routine prints the output of the area correlation.

At present the upper and lower thresholds used for the three level quantization are preset. Further work will involve defining, modeling, and computer implementation of the threshold processor as shown in Figure 2-6. The digital area correlator simulation is structured to run on the PDP-11/34 MTOS. A typical 32 x 32 correlation surface can be generated in approximately 35 minutes using the MTOS.

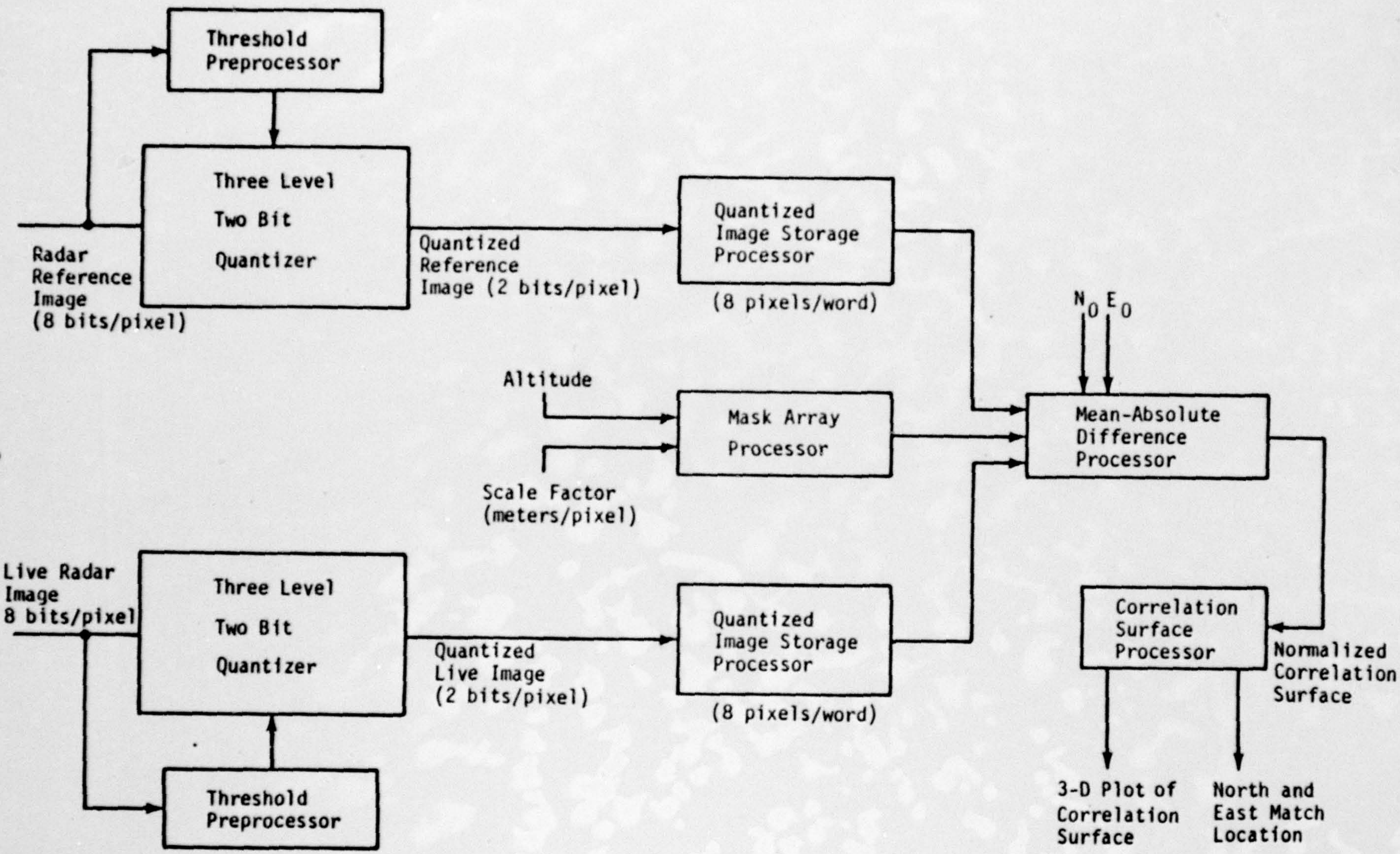

Figure 2-7. Block diagram of digital area correlator simulation.

2.7 Summary

A digital area correlator model has been implemented and incorporated into a digital area correlator simulation on the MTOS. The simulation uses two sets of digitized images, stored on magnetic tape, to calculate a two-dimensional correlation surface via a three level mean-absolute difference algorithm. The simulation produces a plot of the correlation surface and identifies the coordinates at which the best match occurs. Further work will involve exercising the simulation for different reference and live radar image sets.

3. SYSTEM ANALYSIS SUPPORT

PATRIOT system performance was evaluated against advanced threat (1982, 1985, and 1987) scenarios. The studies required that guidance performance be evaluated using MIDAS, guidance simulation, and that surveillance performance be evaluated using the S-1 surveillance simulation. The data were condensed into single-shot engagement kill probability (SSEKP) contours. Results from these studies were documented and presented to the PATRIOT Project Management Office (PMO).